PROF. MINCHIN raises the question of the desirability, or undesirability, of the use of adjectives with regard to physical principles. If the noun deserve the adjective, and if the meaning of the adjective be clear, it is not easy to see why the word should be omitted. Prof. Tait is cited, rather unfortunately, as the leader of those who apply the word "grand" to the principle of conservation of energy, while refraining from its application to certain other physical principles. Whether or not it be the case that "following his lead, all but the most sober mathematicians use the laudatory adjective when they write about this particular physical principle," it is certain that all but the least sober physicists will see a very real reason for the use of the term—precisely the reason which led Tait to adopt it.

Prof. Tait's use of adjectives is instructive. He made a very characteristic use of the term "mere," a word which Prof. Minchin would abolish along with "grand." He spoke of the mere mathematician, that is, a mathematical machine not possessed by the soul of a physicist.

But Tait did not refuse glorification to the principle of conservation of matter. He placed it, in that respect, on the same high level as the principle of conservation of energy. And he glorified Newton's laws, so glorifying the principle of conservation of momentum and the other principles alluded to by Prof. Minchin.

Tait also knew that it was possible so to state the principle of conservation of energy in a dynamical system as to make it include that of conservation of momentum. This was pointed out in an early chapter of a text-book on dynamics which he never completed.

Assume an origin and axes of reference. Let the (conserved) energy of a system be E_1, so that

$$\Sigma(mv^2) = 2E_1.$$

Assume that the energy is also constant ($=E_2$) when the motions are referred to an origin moving uniformly with speed α_2 in a direction making an angle θ with the line of motion of the mass m, and we get

$$\alpha_2^2\Sigma(m) - 2\alpha_2\Sigma(mv\cos\theta) = 2(E_2 - E_1).$$

Similarly

$$\alpha_3^2\Sigma(m) - 2\alpha_3\Sigma(mv\cos\theta) = 2(E_3 - E_2)$$

if we refer to an origin moving with uniform speed α_3 in the same direction. Hence

$$\Sigma(\dot{m}) = 0. \quad \frac{\partial}{\partial t}\Sigma(mv\cos\theta) = 0.$$

The latter equation asserts conservation of momentum, the former asserts conservation of matter.

In the same way, if we postulate that momentum, found to be conserved when referred to certain axes and a given origin, is also conserved when referred to an origin moving uniformly with regard to this reference system, we can deduce the principle of conservation of matter.

It is impossible that all three—matter, momentum, and energy—can be in general found to be conserved simultaneously when referred to an origin in varying motion. If matter be conserved, and if we could measure, from our standpoint on the earth, the momentum and energy of the universe, we should find one or both to be subject to at least yearly, monthly, daily, &c., periodic variations. If the origin move with the centre of inertia, as in all cases directly experimented upon, all three principles hold if two hold, while the energy is found to be constant in at least one state of motion of the centre of inertia, say zero. The discussion of absolute conservation is as futile as the discussion of absolute motion.

It may be that energy, or momentum, is only conserved on the average as to space and time, the departures being on an ultra-measurable scale and yet sufficient to account for "guidance" action in living beings. But we do not require to postulate this in order to account for guidance action. Such action might occur and yet be in accordance with conservation of both momentum and energy. Maxwell's demons could bring it about. Suppose that the mass of a demon is zero, that he is perfectly elastic, and that his parts are capable of rapid relative motion. Let an army of such demons receive orders to abstract heat from one portion of a body and give it to an adjacent portion, so as to establish a difference of temperature while keeping the total energy constant. Because of his zero mass, each demon must adjust himself, in acting upon molecules, so as to produce zero change of momentum at any instant. He can allow quickly moving molecules to pass in one direction, slowly moving molecules in the other, while he prevents to some extent the reverse process. He might thus work railway points with no expenditure of energy on the whole, and with no change of momentum on the whole. The only principle temporarily interfered with is the principle of dissipation of energy; and that is temporarily interfered with constantly in nature.

Such speculations are of no value except as showing that guidance action *may* occur without overthrowing accepted dynamical principles. Further discussion lies outside physics. As Tait said, "human science has its limits, and there are realities with which it is altogether incompetent to deal." A sufficiently wide Monism is scientific and good.

W. PEDDIE.

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IN his letter on the conservation of energy (p. 31), Prof. Minchin holds that, while energy might be conserved in the physical universe acted on in some way by mind, yet neither force nor momentum would be. "They" (the causes altering the configuration of a system) "infallibly alter its total momentum and total force in every direction."

Even for changes produced by physical causes, *e.g.* the pressure of a smooth rail, this may not be the case. It is true the rail will not guide a moving body along it unless it exerts pressure, and then it will generally alter the momentum of the system, to which the rail itself is not supposed to belong. It may happen, however, that the pressure from without is exerted in equal amount in opposite directions. Further, if it were true that the total momentum would be infallibly altered by a *physical* cause, this would prove nothing for psychophysical action, unless we beg the whole question, and assume at the outset that the motion of matter can only be affected by what is material.

The constant use of physical analogy in this connection soon leads to obscurity. The only resemblance that can at present be said to exist between the action of mind and that of an ideal immovable rail is that both do no work. To explain *how* mind acts on matter, such analogies are useless. At most, in the case under discussion, they can only serve to show that there are possible causes of change which do not affect the energy. It is only, I think, an undue use of physical analogy—the action of the mind, for instance, being thought of as pressure—that can prompt the statement that any cause of change must alter the total momentum in some direction.

The laws of mechanics are merely regulative, and are not of themselves sufficient to account for the motion of a dynamical system with given initial conditions, unless it is stipulated that all action is mechanical, or at least unless the action on, or interference with, the motion is exactly defined. This is proved by the simple fact that we can solve examples in dynamics in which we suppose arbitrary, known interference to take place. In such examples, as a rule, the momentum of the system would be altered, but that is not at all necessary.

In conclusion, then, it may be agreed that the action of mind does not violate the laws of mechanics, but that no more prevents mind producing changes than it prevents those produced by ordinary mechanical action.

The University, Birmingham. C. T. PREECE.

Extension of Kelvin's Thermoelectric Theory.

LORD KELVIN'S thermoelectric theory has always seemed to me to be one of his best works. Since its enunciation the scope of the electric current has been extended, as in Maxwell's theory. It is now the curl of the magnetic force of the field always and everywhere. A corresponding extension of the thermoelectric theory is needed. I do not know whether it has been done, but it may be shortly stated, and contains some striking results. As regards the necessity, the following case will show it plainly. Make up a circuit of two parallel wires of different materials, both thermoelectrically neutral, say one of lead, the other of one of Tait's alloys. The places of thermoelectric force in the circuit are then the terminals. Now send short waves along the circuit, in the way so often done of late years. There need be no current at all in the circuit at one end to pair with that at

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the other. So there is complete failure of the theory of metallic circuits.

But the needed extension is easily made by following Lord Kelvin's method, and using the enlarged meaning of electric current. Let $\mathbf{e}$ be the intrinsic voltage per unit length due to reversible thermal action, and let $\mathbf{C}$ be the current density. Then $\mathbf{eC}$ is the heat per unit volume absorbed per second, and the second thermodynamic law requires that $\Sigma\mathbf{eC}/\theta=0$, if θ is temperature, the summation to be complete as regards $\mathbf{e}$. Here $\mathbf{C}$ may be any circuital current, so $\mathbf{e}/\theta$ is polar; that is, $\mathbf{e}=-\theta\nabla p$, where p is a scalar, the thermoelectric power. In a homogeneous conductor, p is a function of the temperature only, to suit Magnus's results. But it is also a function of the material. In what way is not known, but it shows itself at the junction of different metals. Then p changes, say, from p_1 to p_2, so the intrinsic voltage at the junction is $P_{12}=\theta(p_1-p_2)$. This is the Peltier force from the first to the second metal. So far is all that is necessary for steady currents. But when the current varies, part of it leaves the metals. Now at a metal-air junction, the thermoelectric power falls from p to 0, so there is an additional thermoelectric force $P\mathbf{N}$ or $p\theta\mathbf{N}$ acting outwards, $\mathbf{N}$ being the unit normal. It is here assumed that the thermoelectric power of air is zero. It does not seem likely that its value is important compared with p in a metal. This $P\mathbf{N}$ multiplied by the current leaving the conductor measures the reversible thermal effect at the boundary. The system is now complete, provided there is no external $\mathbf{e}$. But should there be, then it must be counted too, if, for instance, a current is induced in an external conductor. In any case, $\mathbf{e}=-\theta\nabla p$ will be valid, with the usual proper interpretation of discontinuities, and the Maxwellian meaning of the current.

It will be sufficient to suppose that $p=0$ outside a circuit of two metals. Then there is the Thomson force in the metals, the Peltier force at the metal junctions, and the metal-air force $P\mathbf{N}$ of variable intensity all over the circuit. In the extreme case with which I commenced, there may be only one Peltier force in operation, or even none at all, but just the metal-air force alone. If so, there is reversible evolution of heat at some parts, and absorption at other parts of the boundary.

As regards the application of the second thermodynamic law, it seems to be justified by experimental results with steady currents. I see no reason why it should not be applied to variable currents, even when varying very rapidly. For p is a property of the material and its temperature at any place, and has nothing to do at the moment with what is going on at other places. Yet a reservation is necessary. For the second law results from averages. So there must be some limit to the rapidity with which the current at any spot may vary, if the second law is to be fully valid there.

The Volta contact force must not be forgotten in connection with the metal-air thermoelectric force. Mr. J. Brown has lately made the Volta force disappear by heating it away in oil. If this is fully confirmed, it perhaps proves that chemical action between the metal and an electrolytic film of moisture is the real source of the energy of the transient Volta current, as Mr. Brown maintains. How will this affect the thermal force? If we allow properly for the change in p in passing through the film from the metal to the air, it seems likely that the thermoelectric effects will be simply superposed upon the Volta effects, because the sources of energy are different. Yet they might have to be combined in some unknown way.

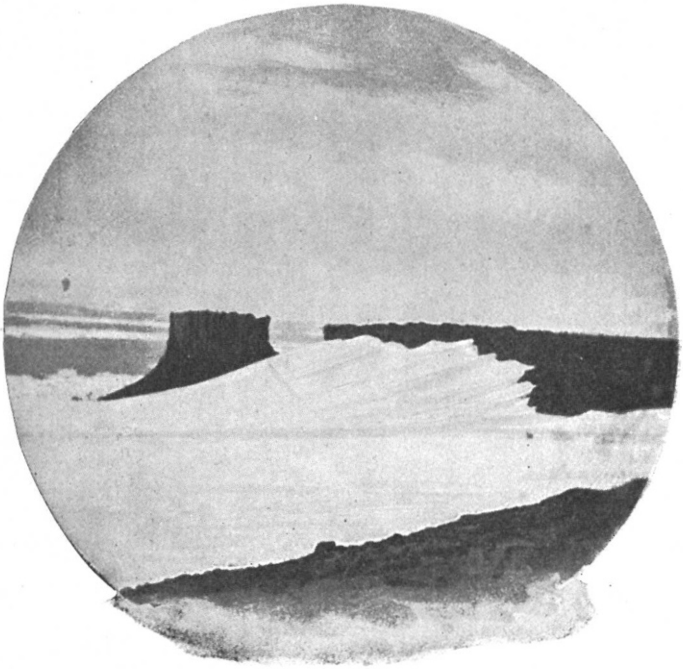
Returning to the steady current in a circuit of two metals, Lord Kelvin showed that the complete intrinsic voltage amounted to $\Sigma p\,d\theta$. This does not express the real distribution of intrinsic force in the circuit, and seems to have no meaning. But it has a curious interpretation, which is of importance in the extended theory. The necessity of the metal-air force is shown in another way. I have shown that the source of $\mathbf{H}$ in varying states is the curl of $\mathbf{e}$ everywhere. Here this is $\mathbf{f}=\mathrm{V}\nabla p\nabla\theta$. It is zero in a homogeneous conductor, and also at the metal junctions, but has the boundary value $\mathrm{V}\mathbf{N}\theta\nabla p$, which would represent the source of $\mathbf{H}$ if there were no metal-air force. But add on the curl of the metal-air force $P\mathbf{N}$ or $p\theta\mathbf{N}$. It is $-\mathrm{V}\mathbf{N}\nabla P$, and the sum of the two is $-\mathrm{V}\mathbf{N}p\nabla\theta$. Now this is also the curl of the fictitious intrinsic force referred to, that is, $p\nabla\theta$ in the metals only. So we come to this striking result, that Lord Kelvin's $\Sigma p\,d\theta$ in the metal circuit alone is a fictitious distribution which not only gives the same steady current as the real distribution of intrinsic force, but also gives the true $\mathbf{E}$ and $\mathbf{H}$ everywhere in variable states as well, provided the real intrinsic forces include the metal-air forces along with the Peltier and Thomson forces.

OLIVER HEAVISIDE.

May 18.

THE FARTHEST NORTH.

H.R.H. Prince Luigi Amedeo of Savoy, Duke of the Abruzzi, has given to the English-reading public a superb account of his great Arctic expedition.[1] Though he has fortunately adopted a smaller size of volume than his Imperial namesake, the Archduke Ludwig Salvator, devotes to his luxurious memoirs on Mediterranean islands, the book is still both ponderous and imposing. Although in octavo, it is as large as most quartos, and it is a credit to the publishers in every way. A royal opulence is reflected from the burnished pages, which reflect the light also so perfectly that at night it is impossible, without elaborate precautions, to prevent the image of the lamp-flame from concealing part of the text. The very fine half-tone reproductions of photographs with which the book is crammed profit by the quality of the paper. The portraits of Admiral Markham and Dr. Nansen, illustrating the introduction, are not, however, very happily chosen, and we miss a satisfactory portrait of Captain Cagni, the hero of the memorable journey to the farthest north.



IG. 1.—Cape Säulen, seen from the south-east. (From "On the *Polar Star* in the Arctic Sea.")

The royal author writes modestly and well, his

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[1] "On the *Polar Star* in the Arctic Sea." By His Royal Highness Luigi Amedeo of Savoy, Duke of the Abruzzi, with the Statements of Commander U. Cagni upon the Sledge Expedition to 86° 34′ N., and of Dr. A. Cavalli Molinelli upon his Return to the Bay of Teplitz. Translated by William Le Queux. In two vols.; with 212 illustrations in the text, 16 full-page photogravure plates, 2 panoramas and 5 maps. Pp. 702 + xxii + xii. (London: Hutchinson and Co., 190)

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